

What is claimed is:

1 1. A wireless communications system comprising:

2 at least four beam formers arranged within a cellular communications
3 network, said beam formers including a first beam former for transmitting a first beam
4 (B1) into a first area and a second beam former for transmitting a second beam (B2) into
5 a second beam area, where said second beam area is adjacent said first beam area, and a
6 third beam former for transmitting a third beam (B3) into a third beam area and a fourth
7 beam former for transmitting a fourth beam (B4) into a fourth beam area, where said
8 fourth beam area is adjacent said third beam area;

9 a mobile switching center for controlling signals transmitted from said at
10 least four beam formers, including sending coded signals along said beams B1, B2, B3
11 and B4 such that:

12 each of said first, second, third and fourth beam areas are effectively
13 divided into at least two sub-areas such that said first beam area includes sub-areas G1₁
14 and G2₁, said second beam area includes sub-areas G1₂ and G2₂, said third beam area
15 includes sub-areas G1₃ and G2₃, and said fourth beam area includes sub-areas G1₄ and
16 G2₄; and

17 wherein during a first time period (T1), simultaneous transmissions
18 are made for receipt by mobile units located within sub-areas G1₁, G1₂, G1₃ and G1₄;

19 during a second time period (T2), transmissions are made for receipt
20 by mobile units located within sub-areas G2₁ and G2₄; and

21 during a third time period (T3), transmissions are made for receipt
22 by mobile units located within sub-areas G2₂ and G2₃.

1 2. The wireless communications system according to Claim 1, wherein
2 said sub-areas G1₁, G1₂, G1₃ and G1₄ are areas with little or no interference from adjacent
3 beams and said sub-areas G2₁, G2₂, G2₃ and G2₄ are areas with greater interference from
4 adjacent beams.

1 3. The wireless communications system according to Claim 1, wherein:
2 said sub-area G1₁ begins near an apex of said first area and extends
3 generally down a center of said first area, and said sub-area G2₁ is located outside of said
4 sub-area G1₁; and

5 said sub-area G1₂ begins near an apex of said second area and extends
6 generally down a center of said second area, and said sub-area G2₂ is located outside of
7 said sub-area G1₂.

8 4. The wireless communications system according to Claim 1 wherein
1 said first and second areas are divided into sub-areas G1₁, G2₁, G1₂, and G2₂ based upon
2 the carrier-to-interference ratio (C/I) of signals being received within each sub-area.

3 5. The wireless communications system according to Claim 1, wherein
4 said beams B1, B2, B3 and B4 are each rotated by half of the average beamwidth of all
5 of the beams, thereby creating new sub-areas RG1₁ and RG2₁ in said first beam area, new
6 sub-areas RG1₂ and RG2₂ in said second beam area, new sub-areas RG1₃ and RG2₃ in
7 said third beam area and new sub-areas RG1₄ and RG2₄ in said fourth beam area, so that
8 each mobile now has the option of selecting from either the rotated beams or the original
 beams, giving rise to more directed beams for the mobiles, thereby increasing both
 coverage and overall throughput.

1 6. The wireless communications system according to Claim 1, wherein
2 said beams B1, B2, B3 and B4 are each rotated by a portion of their
3 beamwidth that is approximately equal to 1/nth of the average beamwidth, where n is the
4 total number of rotated positions for each beam, thereby creating new sub-areas, and
5 further wherein said new sub-areas are served by time periods other than
6 said first, second and third time periods.

1 7. The wireless communications system according to Claim 5, wherein:
2 during a fourth time period (T4), simultaneous transmissions are made for
3 receipt by mobile units located within said sub-areas RG1₁, RG1₂, RG1₃ and RG1₄;
4 during a fifth time period (T5), transmissions are made for receipt by mobile
5 units located within said sub-areas RG2₁ and RG2₄; and
6 during a sixth time period (T6), transmissions are made for receipt by
7 mobile units located within said sub-areas RG2₂ and RG2₃.

1 8. The wireless communications system according to Claim 7, wherein
2 each mobile unit is assigned to a beam and a rotation position based on the following
3 criteria, wherein, for a given mobile, the best rates from all the beams that can be
4 supported in said time slots T1, T2, T3, T4, T5 and T6 are, respectively, r1, r2, r3, r4, r5
5 and r6, and further wherein R1 = max (r1, r4) and R2 = max (r2, r3, r5, r6):

6 if $2R1 \geq R2$ and $r1 \geq r4$, then mobile unit is served in said sub-area G1₁,
7 G1₂, G1₃ or G1₄;
8 if $2R1 \geq R2$ and $r1 < r4$, then mobile unit is served in said sub-area RG1₁,
9 RG1₂, RG1₃ or RG1₄;
10 if $2R1 < R2$ and $\max (r2, r3) > \max (r5, r6)$ and $r2 \geq r3$, then mobile unit
11 is served in said sub-area G2₁ or G2₄;

12 if $2R1 < R2$ and $\max(r2, r3) > \max(r5, r6)$ and $r2 < r3$, then mobile unit
13 is served in said sub-area $G2_2$ or $G2_3$;
14 if $2R1 < R2$ and $\max(r2, r3) \leq \max(r5, r6)$ and $r5 \geq r6$, then mobile unit
15 is served in said sub-area $RG2_1$ or $RG2_4$; and
16 if $2R1 < R2$ and $\max(r2, r3) \leq \max(r5, r6)$ and $r5 < r6$, then mobile unit
17 is served in said sub-area $RG2_2$ or $RG2_3$.

9. A wireless communications system comprising:

10 at least four beam formers arranged within a cellular communications
11 network, said beam formers including a first beam former for transmitting a first beam
12 (B1) into a first area and a second beam former for transmitting a second beam (B2) into
13 a second beam area, where said second beam area is adjacent said first beam area, and a
14 third beam former for transmitting a third beam (B3) into a third beam area and a fourth
15 beam former for transmitting a fourth beam (B4) into a fourth beam area, where said
16 fourth beam area is adjacent said third beam area;

17 a mobile switching center for controlling signals transmitted from said at
18 least four beam formers, including sending coded signals along said beams B1, B2, B3
19 and B4 such that:

20 each of said first, second, third and fourth beam areas are effectively
21 divided into at least two sub-areas such that said first beam area includes sub-areas $G1_1$
22 and $G2_1$, said second beam area includes sub-areas $G1_2$ and $G2_2$, said third beam area
23 includes sub-areas $G1_3$ and $G2_3$, and said fourth beam area includes sub-areas $G1_4$ and
24 $G2_4$; and

25 wherein a group of frequencies are assigned to all of said beam areas
26 within a single cell;

27 further wherein said assigned group of frequencies is divided such
28 that half of said assigned group of frequencies serve mobile units located within sub-areas

21 G1₁, G1₂, G1₃ and G1₄, and the other half of said assigned group of frequencies serve
22 mobile units located within sub-areas G2₁, G2₂, G2₃ and G2₄.

1 10. The wireless communications system according to Claim 9, wherein:
2 the group of frequencies assigned to sub-areas G2₁, G2₂, G2₃ and G2₄ is
3 again divided in half, with one sub-group of this group being assigned to sub-areas G2₁
4 and G2₄ and the other sub-group being assigned to sub-areas G2₂ and G2₃.

1 11. The wireless communications system according to Claim 9,
2 said sub-area G1₁ begins near an apex of said first area and extends
3 generally down a center of said first area, and said sub-area G2₁ is located outside of said
4 sub-area G1₁; and

5 said sub-area G1₂ begins near an apex of said second area and extends
6 generally down a center of said second area, and said sub-area G2₂ is located outside of
7 said sub-area G1₂.

1 12. The wireless communications system according to Claim 9, wherein
2 said beams B1, B2, B3 and B4 are each rotated by half of the average
3 beamwidth of all of the beams, thereby creating new sub-areas RG1₁ and RG2₁ in said
4 first beam area, new sub-areas RG1₂ and RG2₂ in said second beam area, new sub-areas
5 RG1₃ and RG2₃ in said third beam area and new sub-areas RG1₄ and RG2₄ in said fourth
6 beam area, so that each mobile now has the option of selecting from either the rotated
7 beams or the original beams, giving rise to more directed beams for the mobiles, thereby
8 increasing both coverage and overall throughput; and

9 further wherein each of said new sub-areas RG1₁, RG2₁, RG1₂, RG2₂, RG1₃,
10 RG2₃, RG1₄ and RG2₄ are served by different frequencies than said sub-areas G1₁, G2₁,
11 G1₂, G2₂, G1₃, G2₃, G1₄, and G2₄.

1 13. A method for reducing interference in a wireless system including
2 at least two beam formers and a plurality of mobile units, the method comprising the steps
3 of:

4 transmitting a first beam (B1) from a first beam former into a first area,
5 defining two sub-areas within said first area as sub-area G1₁ and sub-area G2₁;

6 transmitting a second beam (B2) from a second beam former into a second
7 area, defining two sub-areas within said second area as sub-area G1₂ and sub-area G2₂;

8 coding signals of said beams B1 and B2 for receipt by a particular mobile
9 unit based upon whether the particular mobile unit is located within said sub-area G1₁,
10 said sub-area G2₁, said sub-area G1₂ or said sub-area G2₂, such that:

11 during a first time period (T1), making simultaneous transmissions
12 from both said first and second beam formers for receipt by mobile units located,
13 respectively, within said sub-area G1₁, or within said sub-area G1₂;

14 during a second time period (T2), making transmissions from said
15 first beam former for receipt by mobile units located within said sub-area G2₁; and

16 during a third time period (T3), making transmissions from said
17 second beam former for receipt by mobile units located within said sub-area G2₂.

1 14. The method according to Claim 13, wherein:

2 said first area is adjacent to said second area;

3 said sub-area G1₁ begins near an apex of said first area and extends
4 generally down a center of said first area, and said sub-area G2₁ is located outside of said
5 sub-area G1₁; and

6 said sub-area G1₂ begins near an apex of said second area and extends
7 generally down a center of said second area, and said sub-area G2₂ is located outside of
8 said sub-area G1₂.

1 15. The method according to Claim 14, wherein said sub-areas G₁₁ and
2 G₁₂ are each generally teardrop-shaped.

1 16. The method according to Claim 13, wherein said first and second
2 areas are divided into said sub-areas G₁₁, G₂₁, G₁₂, and G₂₂ based upon the carrier-to-
3 interference ratio (C/I) of signals being received within each sub-area.

1 17. The method according to Claim 13, wherein a mobile unit is assigned
2 to one of said sub-areas G₁₁, G₂₁, G₁₂, and G₂₂ according to the following process:

3 measuring the carrier-to-interference ratio (C/I) for a mobile unit during a
4 4/4 cycle to define a first rate;

5 measuring the carrier-to-interference ratio (C/I) for a mobile unit during a
6 2/4 cycle to define a second rate; and

7 comparing said first rate to said second rate, and if said second rate is
8 larger than twice said first rate, assigning said mobile unit to said sub-area G₂₁ for said
9 beam B₁, or to said sub-area G₂₂ for said beam B₂, otherwise said mobile unit is assigned
10 to said sub-area G₁₁ for said beam B₁, or to said sub-area G₁₂ for said beam B₂.

1 18. The method according to Claim 13, further comprising:
2 transmitting a third beam (B₃) from a third beam former into a third area,
3 defining two sub-areas within said third area as sub-area G₁₃ and sub-area G₂₃;

4 transmitting a fourth beam (B₄) from a fourth beam former into a fourth
5 area, defining two sub-areas within said fourth area as sub-area G₁₂ and sub-area G₂₂;

6 coding signals of said beams B₃ and B₄, such that:

7 during said period T₁, making simultaneous transmissions from said
8 third and fourth beam formers for receipt by mobile units located, respectively, within
9 said sub-area G₁₃ or within said sub-area G₁₄; and

19. The method according to Claim 13, wherein said time period T1 is longer than both said time period T2 and said time period T3.

20. The method according to Claim 19, wherein said time period T2 is approximately equal in duration to said time period T3.

21. The method according to Claim 13, wherein said time periods T1, T2 and T3 are determined according to the formula $T1/(T2 + T3) = N1/N2 = X$, where N1 is the number of mobile units assigned to said sub-area G1₁ for said beam B1 or to said sub-area G1₂ for said beam B2, N2 is the number of mobile units assigned to said sub-area G2₁ for said beam B1 or to said sub-area G2₂ for said beam B2, and X is a predetermined constant.

22. The method according to Claim 18, further comprising:
 rotating beams B1, B2, B3 and B4 by a portion of their respective beamwidths, thereby creating new sub-areas RG1₁ and RG2₁ in said first beam area, new sub-areas RG1₂ and RG2₂ in said second beam area, new sub-areas RG1₃ and RG2₃ in said third beam area and new sub-areas RG1₄ and RG2₄ in said fourth beam area; and
 coding signals of said beams B1, B2, B3 and B4 such that:

during a fourth time period (T4), simultaneous transmissions are made for receipt by mobile units located within said sub-areas $RG1_1$, $RG1_2$, $RG1_3$ and $RG1_4$;

during a fifth time period (T5), transmissions are made for receipt by mobile units located within said sub-areas RG2₁ and RG2₄; and

during a sixth time period (T6), transmissions are made for receipt by mobile units located within said sub-areas RG2₂ and RG2₃.

23. A method for reducing interference in a wireless system including at least four beam formers and a plurality of mobile units, the method comprising the steps of:

transmitting a first beam (B1) from a first beam former into a first area; transmitting a second beam (B2) from a second beam former into a second area;

transmitting a third beam (B3) from a third beam former into a third area; transmitting a fourth beam (B4) from a fourth beam former into a fourth area;

defining at least two sub-areas within each of said first, second, third and fourth beam areas based upon the degree of overlap with adjacent beam areas, whereby each of said beam areas includes at least one overlapping sub-area and at least one non-overlapping sub-area; and

coding signals of said beams B1, B2, B3 and B4 for receipt by a particular mobile unit based upon which of said sub-areas the particular mobile unit is located within.

24. The method according to Claim 23, wherein said coding is divided into at least three sequential time periods such that the method includes the following additional steps:

during a first time period (T1), making simultaneous transmissions from all four of said beam formers for receipt by mobile units located within said non-overlapping sub-areas;

during a third time period (T3), making transmissions from said second and third beam formers for receipt by mobile units located within said overlapping sub-areas within said second and fourth areas.

25. The method according to Claim 23, further comprising the steps of:

defining at least a third sub-area within each of said first, second, third and areas based upon the degree of overlap with adjacent beam areas, whereby beam areas includes at least one non-overlapping sub-area and at least two sub-areas, further defined as a first overlapping sub-area and a second sub-area;

comparing the strength of each beam signal within a particular sub-area to determine whether a particular mobile unit is located within said non-overlapping sub-area, said first overlapping sub-area or said second overlapping sub-area.

26. The method according to Claim 25, further comprising the steps of:

determining that a particular mobile unit is located within said non-overlapping sub-area if the strength of all beam signals but one are less than a threshold value Y_1 ;

determining that a particular mobile unit is located within said first overlapping sub-area if the difference between signal strengths from adjacent beams is

7 less than a threshold value Y2, and the signal strength of said two adjacent beams
8 combined is greater than a threshold value Y3; and

9 determining that a particular mobile unit is located within said second
10 overlapping sub-area if the difference between signal strengths from adjacent beams is
11 less than said threshold value Y3.

27. The method according to Claim 26, wherein said threshold values
Y1, Y2 and Y3 are all different values from each other.

28. The method according to Claim 23, further comprising the steps of:

2 effectively dividing each of said first, second, third and fourth beam
3 areas into at least two sub-areas such that said first beam area includes sub-areas G1₁ and
4 G2₁, said second beam area includes sub-areas G1₂ and G2₂, said third beam area includes
5 sub-areas G1₃ and G2₃, and said fourth beam area includes sub-areas G1₄ and G2₄; and
6 assigning a group of frequencies to all of said beam areas within a

7 single cell;

8 dividing said assigned group of frequencies such that half of said
9 assigned group of frequencies serve mobile units located within sub-areas G1₁, G1₂, G1₃
10 and G1₄, and the other half of said assigned group of frequencies serve mobile units
11 located within sub-areas G2₁, G2₂, G2₃ and G2₄.

1 29. The method according to Claim 23, further comprising the steps of
2 dividing the group of frequencies assigned to sub-areas G2₁, G2₂, G2₃ and G2₄ in half
3 again, and assigning one sub-group of this group to sub-areas G2₁ and G2₄ and assigning
4 the other sub-group to sub-areas G2₂ and G2₃.

1 30. A beam forming apparatus for use with a wireless communication
2 system, said beamforming apparatus comprising:

3 means for transmitting a beam into a first area and for defining two sub-
4 areas within said first area as sub-area G1 and sub-area G2;

5 means for coding signals of said beam for receipt by a particular mobile unit
6 based upon whether the particular mobile unit is located within said sub-area G1 or said
7 sub-area G2, such that:

8 during a first time period (T1), making transmissions from said beam
9 former for receipt by mobile units located within said sub-area G1, and

10 during a second time period (T2), making transmissions from said
11 first beam former for receipt by mobile units located within said sub-area G2.

12 31. The beam forming apparatus according to Claim 30, wherein a
13 mobile unit is assigned to one of said sub-areas G1 or G2 by:

14 measuring the carrier-to-interference ratio (C/I) for a mobile unit during a
15 4/4 cycle to define a first rate;

16 measuring the carrier-to-interference ratio (C/I) for a mobile unit during a
17 2/4 cycle to define a second rate; and

18 comparing said first rate to said second rate, and if said second rate is
19 larger than twice said first rate, assigning said mobile unit to said sub-area G2, otherwise
20 said mobile unit is assigned to said sub-area G1.

21 32. A system of signals for use in a wireless communications system
22 including at least a first beam former and a second beam former and a plurality of mobile
23 units, the signals comprising:

24 signals transmitted from the first beam former into a first area, where said
25 first area is divided into at least two sub-areas defined as sub-area G1, and sub-area G2;

6 signals transmitted from the second beam former into a second area, where
7 said second area is divided into at least two sub-areas defined as sub-area G₁₂ and sub-
8 area G₂₂;

9 coding said signals from said first and second beam formers for receipt by
10 a particular mobile unit based upon whether the particular mobile unit is located within
11 said sub-area G₁₁, said sub-area G₂₁, said sub-area G₁₂ or said sub-area G₂₂, such that:

12 signals transmitted during a first time period (T1) are transmitted
13 simultaneously from both said first and second beam formers for receipt by mobile units
14 located, respectively, within said sub-area G₁₁, or within said sub-area G₁₂;

15 signals transmitted during a second time period (T2) are transmitted
16 from said first beam former for receipt by mobile units located within said sub-area G₂₁;
17 and

18 signals transmitted during a third time period (T3) are transmitted
19 from said second beam former for receipt by mobile units located within said sub-area
20 G₂₂.

1 33. The system of signals according to Claim 32, wherein:

2 said first area is adjacent to said second area;

3 said sub-area G₁₁ begins near an apex of said first area and extends
4 generally down a center of said first area, and said sub-area G₂₁ is located outside of said
5 sub-area G₁₁; and

6 said sub-area G₁₂ begins near an apex of said second area and extends
7 generally down a center of said second area, and said sub-area G₂₂ is located outside of
8 said sub-area G₁₂.

1 34. The system of signals according to Claim 32, wherein said beams
2 B1, B2, B3 and B4 are each rotated by a portion of their respective beamwidths, thereby

3 creating new sub-areas $RG1_1$ and $RG2_1$ in said first beam area, new sub-areas $RG1_2$ and
4 $RG2_2$ in said second beam area, new sub-areas $RG1_3$ and $RG2_3$ in said third beam area
5 and new sub-areas $RG1_4$ and $RG2_4$ in said fourth beam area, said system further
6 comprising:

7 coding signals of said beams B1, B2, B3 and B4 such that:

8 signals transmitted during a fourth time period (T4) are
9 simultaneously transmitted for receipt by mobile units located within said sub-areas $RG1_1$,
10 $RG1_2$, $RG1_3$ and $RG1_4$;

11 signals transmitted during a fifth time period (T5) are transmitted for
12 receipt by mobile units located within said sub-areas $RG2_1$ and $RG2_4$; and

13 signals transmitted during a sixth time period (T6) are transmitted
14 for receipt by mobile units located within said sub-areas $RG2_2$ and $RG2_3$.

1 35. The system of signals according to Claim 32, wherein each mobile
2 unit is assigned to a beam and a rotation position based on the following criteria, wherein,
3 for a given mobile, the best rates from all the beams that can be supported in said time
4 slots T1, T2, T3, T4, T5 and T6 are, respectively, $r1$, $r2$, $r3$, $r4$, $r5$ and $r6$, and further
5 wherein $R1 = \max(r1, r4)$ and $R2 = \max(r2, r3, r5, r6)$:

6 if $2R1 \geq R2$ and $r1 \geq r4$, then mobile unit is served in said sub-area $G1_1$,
7 $G1_2$, $G1_3$ or $G1_4$;

8 if $2R1 \geq R2$ and $r1 < r4$, then mobile unit is served in said sub-area $RG1_1$,
9 $RG1_2$, $RG1_3$ or $RG1_4$;

10 if $2R1 < R2$ and $\max(r2, r3) > \max(r5, r6)$ and $r2 \geq r3$, then mobile unit
11 is served in said sub-area $G2_1$ or $G2_4$;

12 if $2R1 < R2$ and $\max(r2, r3) > \max(r5, r6)$ and $r2 < r3$, then mobile unit
13 is served in said sub-area $G2_2$ or $G2_3$;

14 if $2R1 < R2$ and $\max(r2, r3) \leq \max(r5, r6)$ and $r5 \geq r6$, then mobile unit
15 is served in said sub-area $RG2_1$ or $RG2_4$; and
16 if $2R1 < R2$ and $\max(r2, r3) \leq \max(r5, r6)$ and $r5 < r6$, then mobile unit
17 is served in said sub-area $RG2_2$ or $RG2_3$.